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Influence of the Lubrication Conditions on the Surface Finish of Turned Aeronautical Aluminium Alloys. A preliminary Study

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1. Introduction – Nowadays, one of the main objectives that affects the development of any new product is the respect for the environment. Until the late 80's, the development and manufacture of the most of the product were aimed to achieve maximum quality in time and costs with environmental issues relegated to secondary importance. On the other hand, in the 90's, the pressure from factors such as markets, financial and legislative factors, led to environmental considerations being taken into account.

In this context, the current aeronautical industry strategies are based on the search for economic, environmental and energy efficiency considerations for all the processes involved in the aircraft manufacturing.

In fact, the current tendency in the aircraft industry is the implementation of Advanced Manufacturing Systems, such as Lean Manufacturing, including a series of principles, concepts and techniques designed to remove everything that does not add value to the product, optimizing by this way the quality through continuous improvement of manufacturing processes [1].

One of the manufacturing processes that plays a high relevance role in this industry is the machining of light alloys, mostly aluminum alloys. A high number of structural Al based elements are placed in sensitive zones with a high compromise in respect to aircraft safety.

Following some of the pervious considerations, the current tendency in this process is to reduce energy and costs, by means of elimination of intermediate steps, which does not provides value to the product achievement, and at the same time, to perform all the machining process in the absence of cutting fluids, and by this way reaching an environmentally friendly process. However, the total suppression of these fluids involves to work under very aggressive conditions. This new situation makes necessary to look for combinations of cutting parameters and types of tools that optimize the machining in those extreme work conditions with the purpose of obtaining a quality level in products according to the demanded specifications and with a cost as low as possible [1,2].

On the other hand, the quality obtained after the machining process directly affects the functionality of the manufactured parts or components [1,3,4]. The way to evaluate the process quality is commonly carried out through the surface integrity analysis, understanding this as the relationship between various aspects which include macro and microgeometric aspects. The particular aim of this work is the elaboration of a comparative study of the surface finish generated in dry and cooled machining process for Aluminum-Copper alloy UNS A92024-T351.

2. Experimental Procedure – In order to evaluate the surface finish in terms of Roughness Average (Ra) sheets of aluminum alloy UNS A92024-T351, has been used as starting material, with composition as shown in Table I.

Table I. Composition of aluminum- copper alloy (mass%).

Cu	Mg	Mn	Si	Fe	Zn	Ti	Cr	Al
4.00	1.50	0.60	0.50	0.50	0.25	0.15	0.10	Rest

The Ra evaluation was made on specimens manufactured according to ISO / DIS 1143. The technological parameters used during the machining were: Cutting speeds (Cs) from 40 m / min to 200 m / min , Feeds (f) from 0.05 mm / rev to 0.2 mm / rev, and a fixed depth of cut (p) of 0.5 mm.

The specimens manufacturing process was carried out in various stages. The first step was to split the starting material in order to get 20 parallelepiped with the same size. For this purpose, a band saw was used. Later, these parallelepiped were turned into various operations performing the final machining on a lathe CNC Heildemaster CTX400, Figure 1.

Figure 1: Specimens Manufacturing Process: Initial phase

The process of turning, as already mentioned, was carried out in two phases. First, the parallelepipedal specimens were rough dressed with interchangeable neutral inserts of Tungsten carbide (WC). Finishing process was carried out using TiN coated WC neutral inserts. The last pass was performed according to the prefixed technological parameters in the experimental stage. In order to analyze the influence of the cutting fluids, the machining processes were carried out both in presence and in absence of coolants.
On the other hand, in order to safeguard the test traceability throughout the process of turning, the cutting inserts were identified according to the edge and the specimen to be machined.

Once the samples were prepared, the evaluation of their surface finish was achieved in terms of average roughness, Ra. Roughness measurements were carried out using a roughness tester SM7, Figure 2.

Figure 2: Process of Measurement Roughness Average

3. Main Results – Figure 3 plots the evolution of the values of Roughness Average (Ra) as a function of feed (f) for each cutting speed (Cs) applied. As it can be seen in Figure 3, the general tendency for each Cs, for both dry and cooled tests, is that as feed increases, the surface finish, evaluated in terms of Ra, decreases. In this figure, Ra is an increasing function of feed. This result corroborates results obtained by other authors [3-6]. On the other hand, it can also be seen that Ra values are lower in the case of dry turning tests, and, so, workpieces show a better surface quality than those tested with coolants.

This is because of the instant adhesion arising by dry cutting conditions. In effect, in previous work, it has been proved that in the first instants of the machining process, a pure Al layer is thermo-mechanically developed onto the tool rake face, favoring the posterior formation of the Built-Up Edge -with composition of the alloy- by mechanical adhesion [7]. BUE thickness diminishing the height of grooves generated by the tool in the turning process and, as a consequence of this, the Ra value [1,8]. This fact is more intense when cutting fluids are avoided [9]. Because of all this, when the Al-Cu alloy is dry turning, a better surface finish -evaluated from the Ra values- is achieved. On the other hand, these cutting conditions have a direct impact on the tool life, wearing it out and making its geometry varies. With these cutting conditions a completely unstable process results. The wear caused on the tool, makes that the initial conditions in the process were modified.

Additionally, in the tests made in presence of cutting fluids the adherence process of the material to the tool surface is retarded due to the decrease of the temperature in the cutting zone as the coolant effect of those fluids. So, the thickness of the BUE is lower than the formed in absence of cutting fluids, giving rise to higher values of Ra as a consequence of the minor changes in the tool geometry during the test.

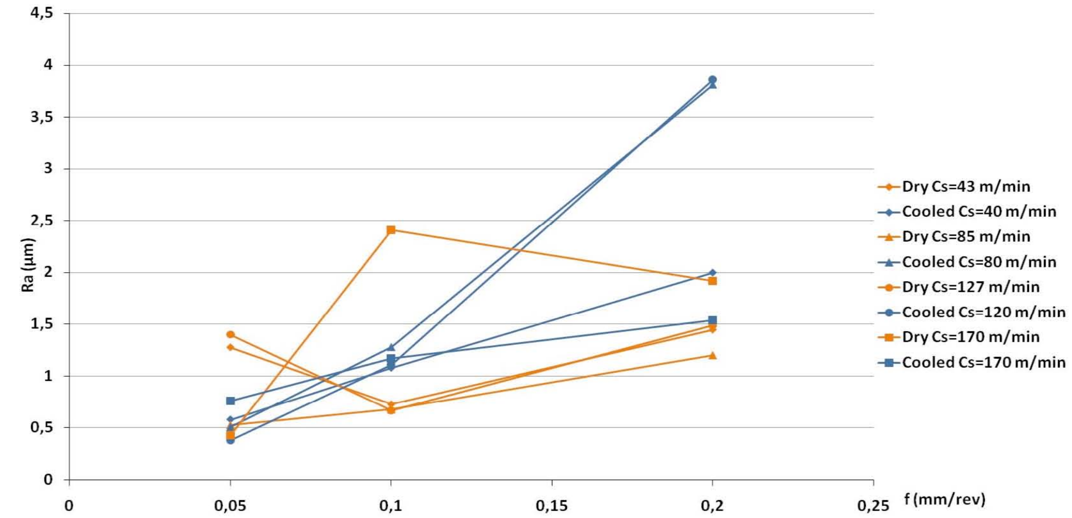

Figure 3: Evolution of Ra as a function of Feed for each Cs

On the other hand, Figure 4 plots the Ra evolution as function of cutting speed for each feed applied, in both dry and cooled tests. In cooled tests, a similar Ra values for each individual feed are achieved as can be seen in each Cs range tested, except in the case of the highest feed. This can be explained in terms of the cutting forces, as it is reflected in [9]. It reinforces the conclusions extracted from Figure 3, taking onto account the decisive influence of feed in the surface finish of the process [5,6].

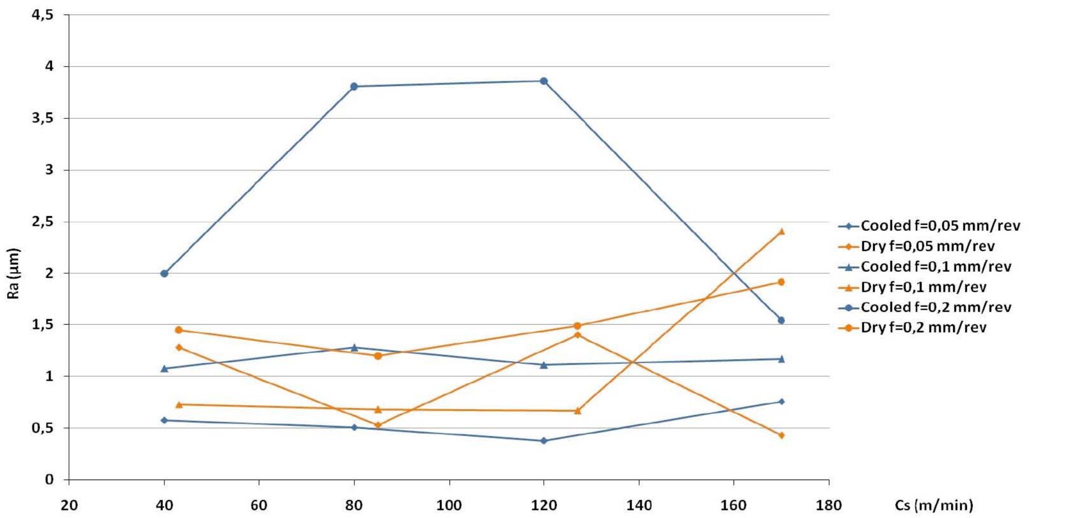

Figure 4. Evolution of Ra as a function of Cs for each Feed

In effect, in the cooled tests, an increase in Cs does not imply a significant improvement in surface finish, as shown in Figure 4. Furthermore, the fact that the machining process is cooled makes that, as has already been mentioned above, the adhesion on the edge of the tool is much lower. This process is more controlled as can be seen in the graphic.

In regard to the tests carried out in the absence of coolants, as can be seen in Figure 4, that as Cs increases for each feed, Ra values, show a higher tendency to growth. This could be associated with a delay in the formation of the effects of adhesion, which is in agreement with previous studies in similar contexts.

In this graph it can also be seen that for the feed of 0.2 mm / rev, the Ra tendency for each Cs does not follow the rule set out in the others cooled cases. In the machining a number of input variables and others that are inherent to the process come into play. Between the latter, the type and formation of the chip, the microstructural characteristics of the material (intermetallic particles) and the processes of tool wear are found [1,8,9]. All these factors can have a negative impact on the surface finish of machined components. It should be noted, further, that disperse results have taken place under the conditions of the higher feeds.

4. Conclusions - A Preliminary Study about the Influence of the Lubrication Conditions on the Surface Finish -measured from Ra values- of cooled and dry turned UNS A92024-T351 alloy has been carried out. From the results obtained it is concluded:

1. Feed has a negative influence on surface finish, evaluated in terms of Roughness Average (Ra) being independence of the machining process, dry or cooled.
2. The roughness average, Ra, achieved in dry machining is better than that achieved by the machining process performed in the presence of cutting fluids. This is caused by the quick formation of BUL and BUE in the case of dry turning. These effects decrease the height of the grooves formed during the machining processes
3. An increase in Cutting speed does not lead to improvement in the values of Ra. Although it reduces the adhesion phenomena appearance in dry machining, which, in such cases, can lead to a slight growth trend of the curves Ra (Cs).
4. From the standpoint of process economics of the machining performed in the presence of fluids, the surface finish obtained does not vary widely in the range of feed between 0.05 and 0.1 mm / rev, for all Cs.
5. The results achieved refer only to geometric aspects. Research is needed into other aspects as well as new geometries and coatings for tools in order to make guaranteed dry machining process.

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